Lamphone

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Mentors:

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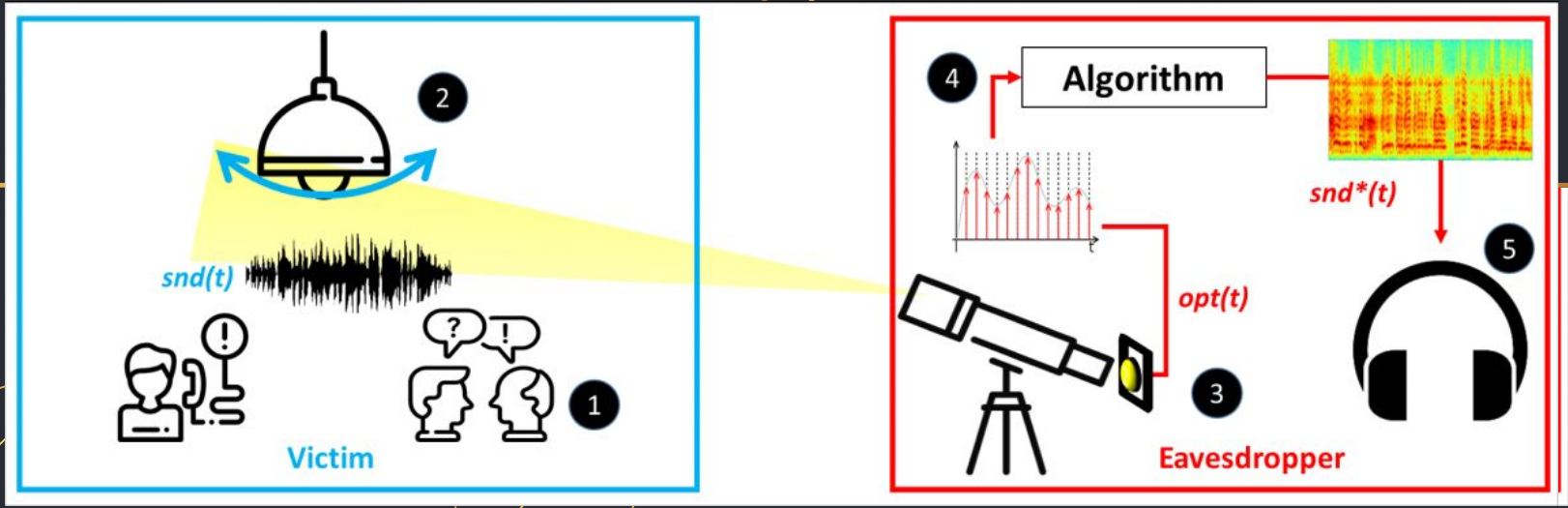
What on earth is lamphone?

A spying device, that can recover speech and sound from a room with a handling bulb in it

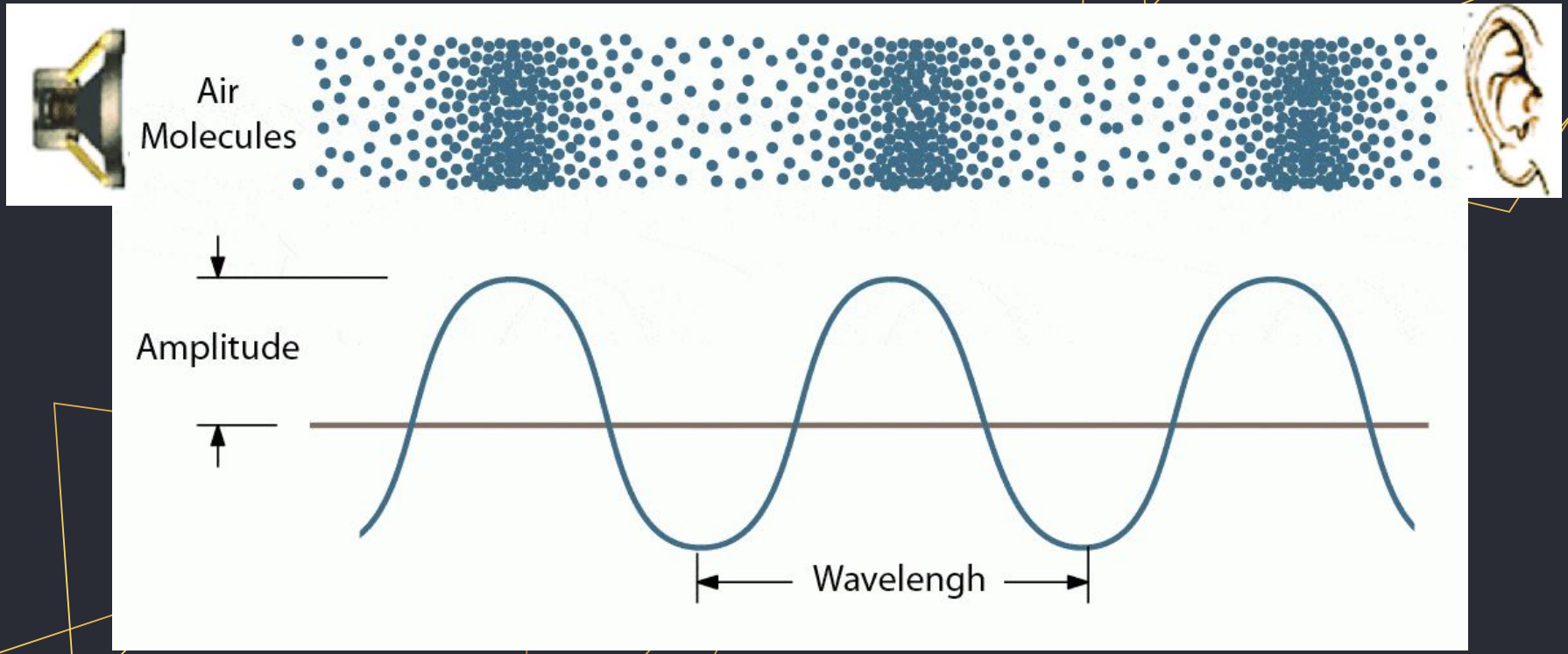
How is it supposed to work?

Sound- vibration, produced by the source*(human,speakers...)*. That vibration makes a handling bulb fluctuate a bit.

At different angles, the brightness of a lamp is different, so we can try to use that fact to retrieve the sound from lamp fluctuations.



Sound wave



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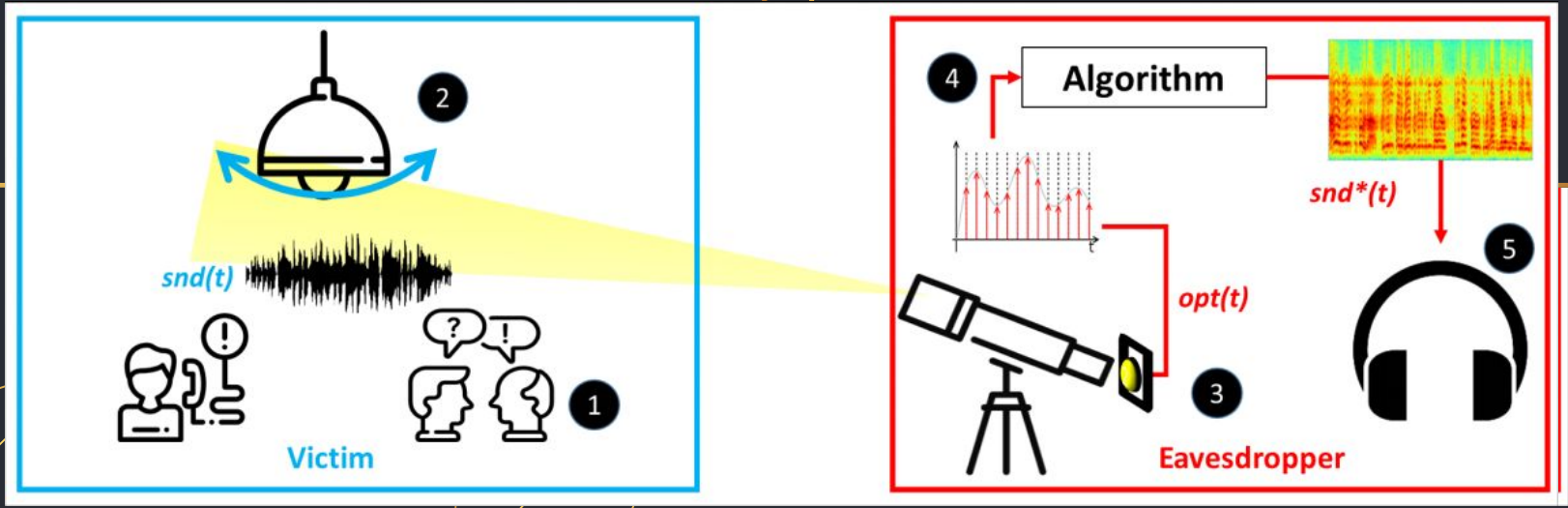
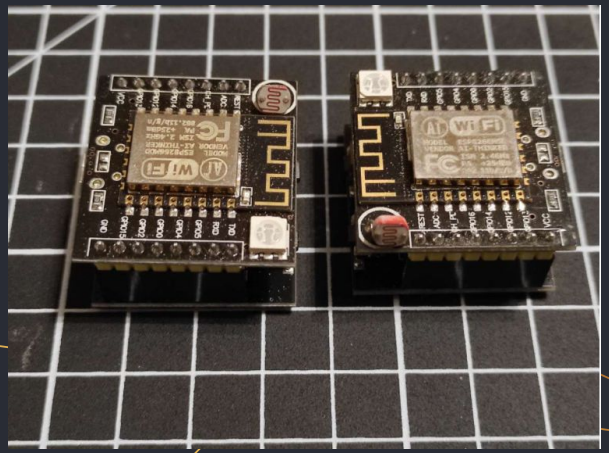


First attempts

ESP8266 Wifi Module
with build-in LDR sensor



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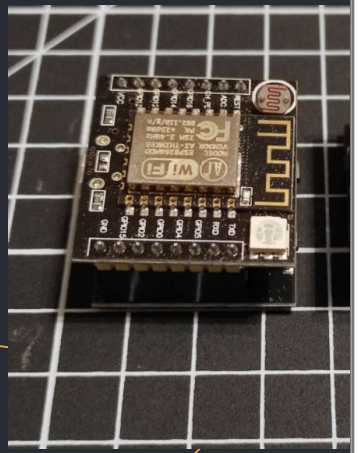
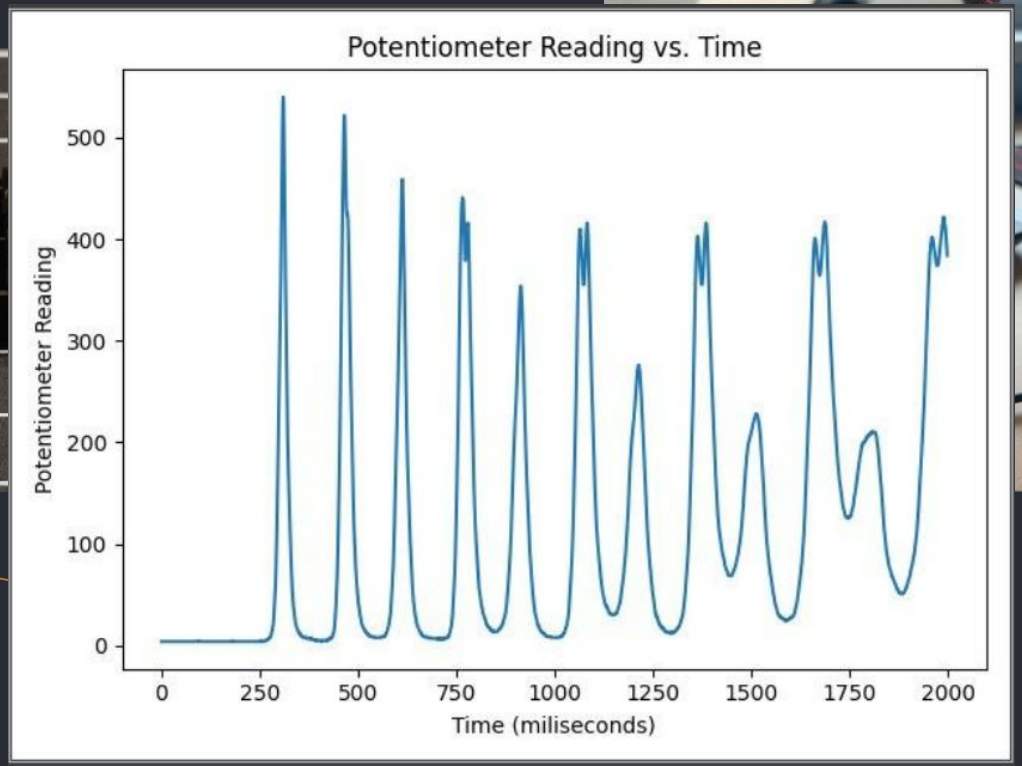
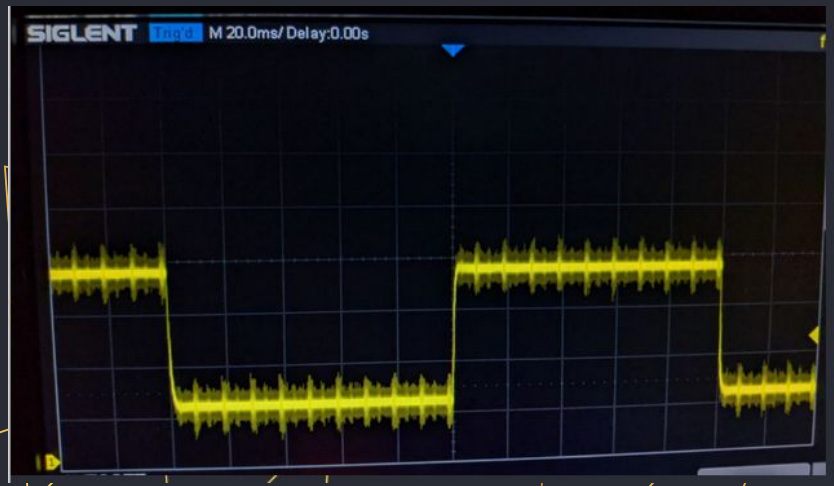




Problem №1: Sluggishness of LDR

10 Hz

Arduino temt6000 (phototransistor)

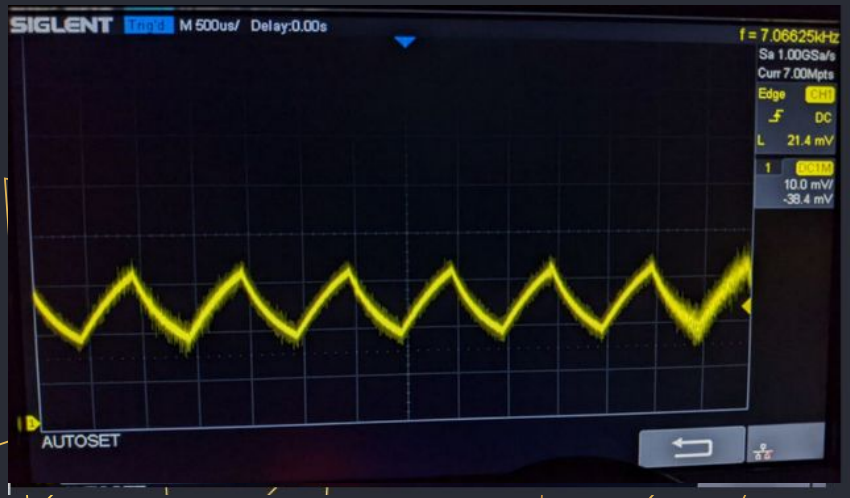


Usual LDR

Sluggishness of LDR

1000 Hz

Arduino temt6000 (phototransistor)

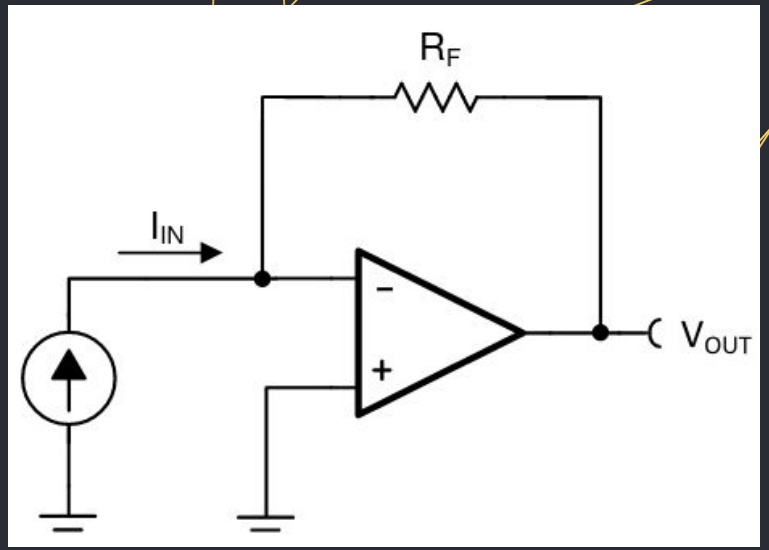


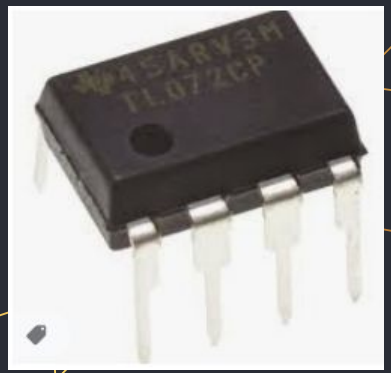
Usual LDR

The Transimpedance Amplifier Circuit

Photodiode (7$)

(BPW20RF)
Frequency: up to 1 Mhz
Sensitive to 400-700 nm

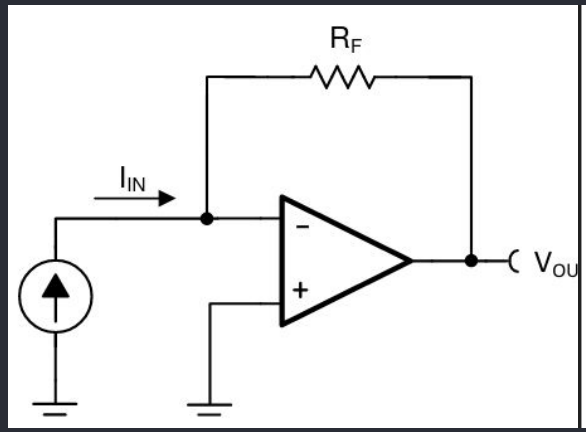


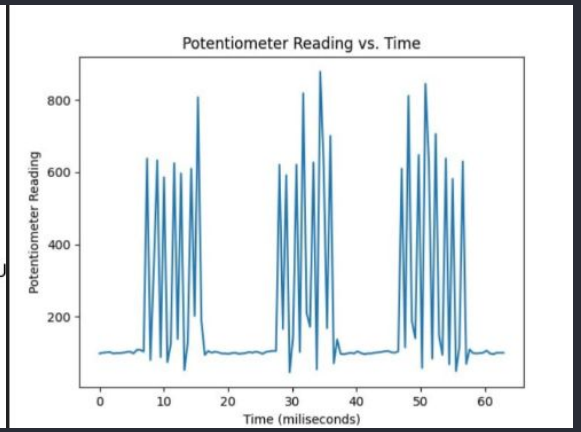


Operational amplifier (1$)

(TL072CP)
Up to 3 Mhz, relatively low noize

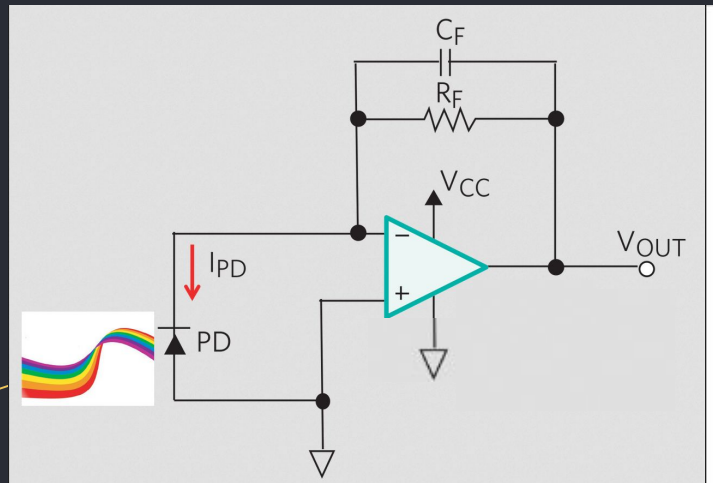
Sequence of 0 and 50%, PWM, same as before

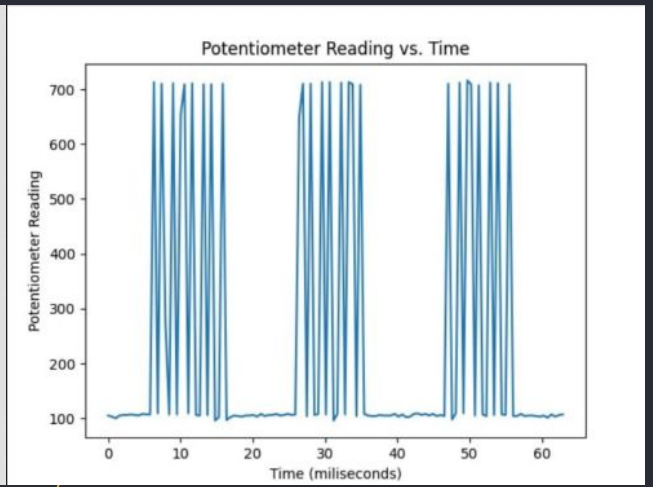




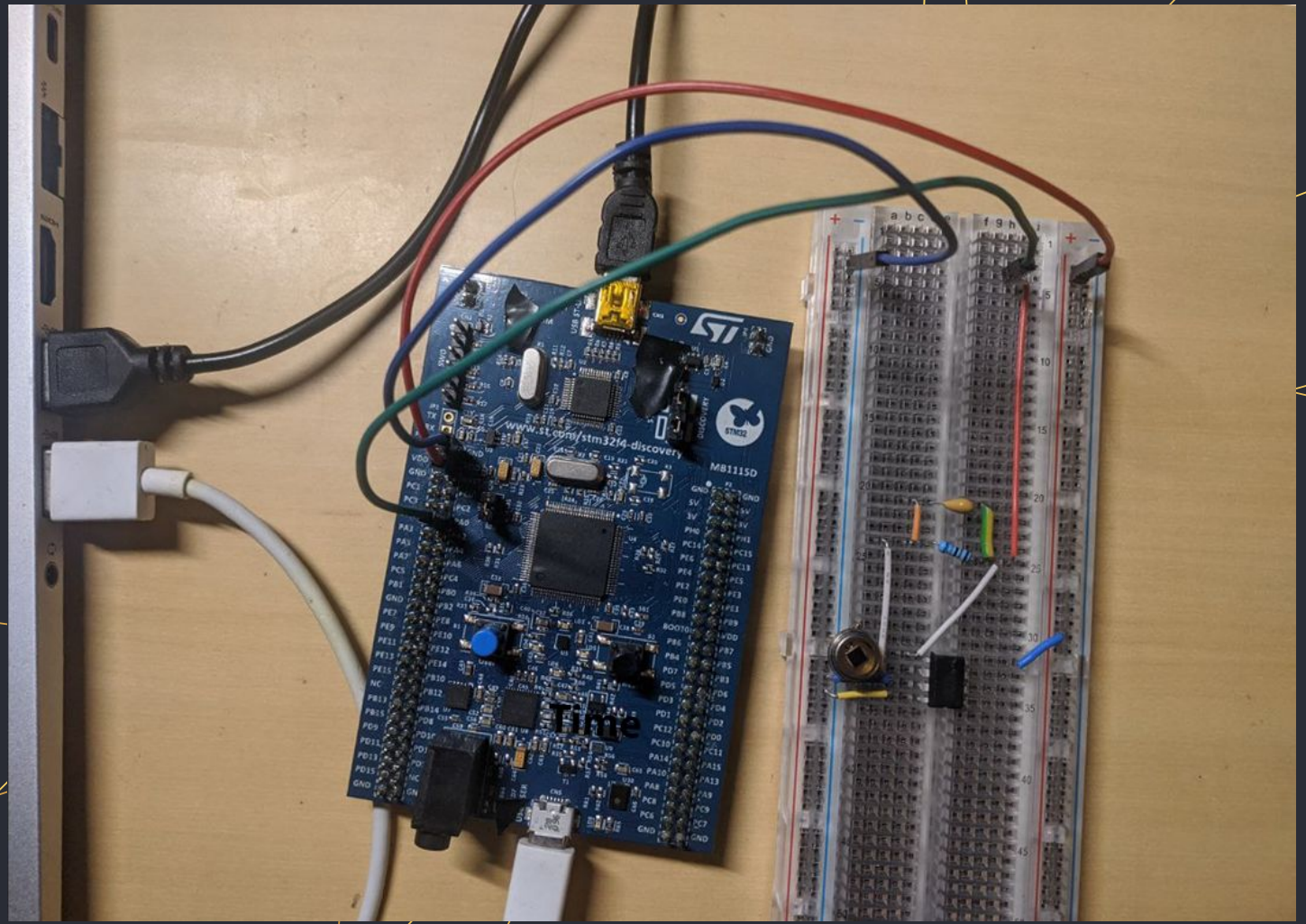
$$V_{OUT} = I_{PD}R_F$$

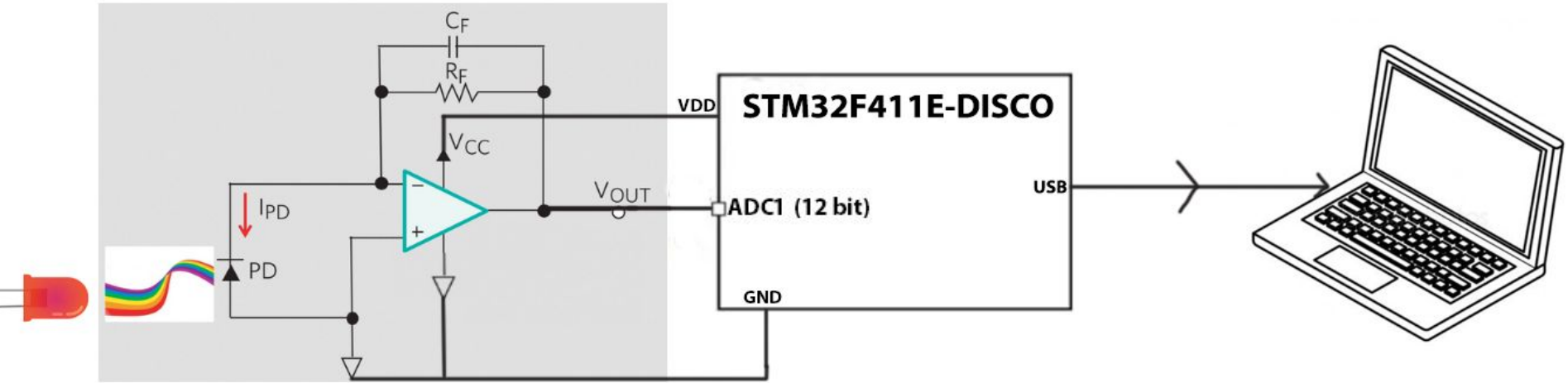
$$C_1 \leq \frac{1}{2\pi R_1 f_P}$$





R_F= 680 kΩ
C_F= 22 pF

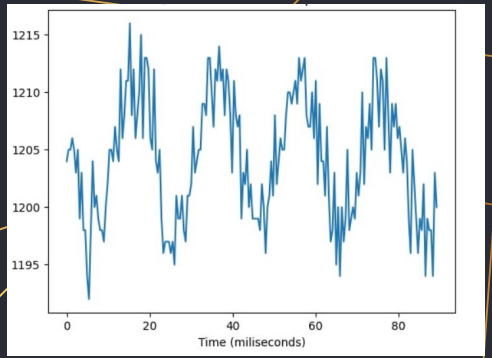

www.st.com/stm32f4-discovery
MB1115D
Time


C_F
R_F
V_{CC}
I_{PD}
PD
V_{OUT}
VDD
STM32F411E-DISCO
ADC1 (12 bit)
GND
USB

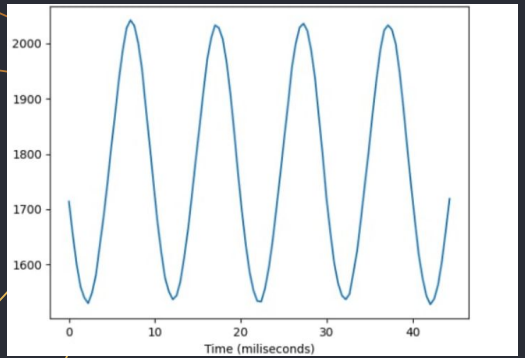
Other problems

- The only team of developers in the world, who succeeded in this task are Israel IoT Ph.D. students with a lot of background and similar projects
  www.nassiben.com/lamphone
- We, who faced embedded for the first time
- Project is more about how to get the signal, than coding itself
- 50Hz electrical grid frequency in European countries

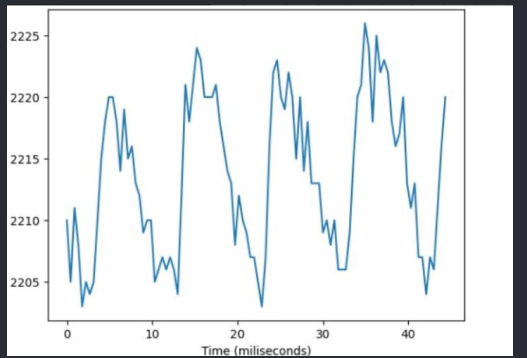
Usual light diode



Incandescent bulb

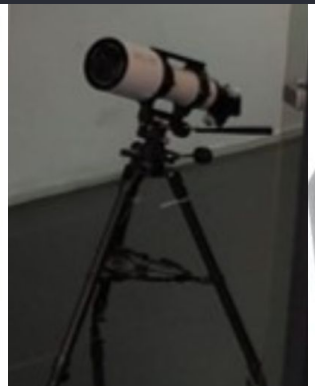


LED- bulb

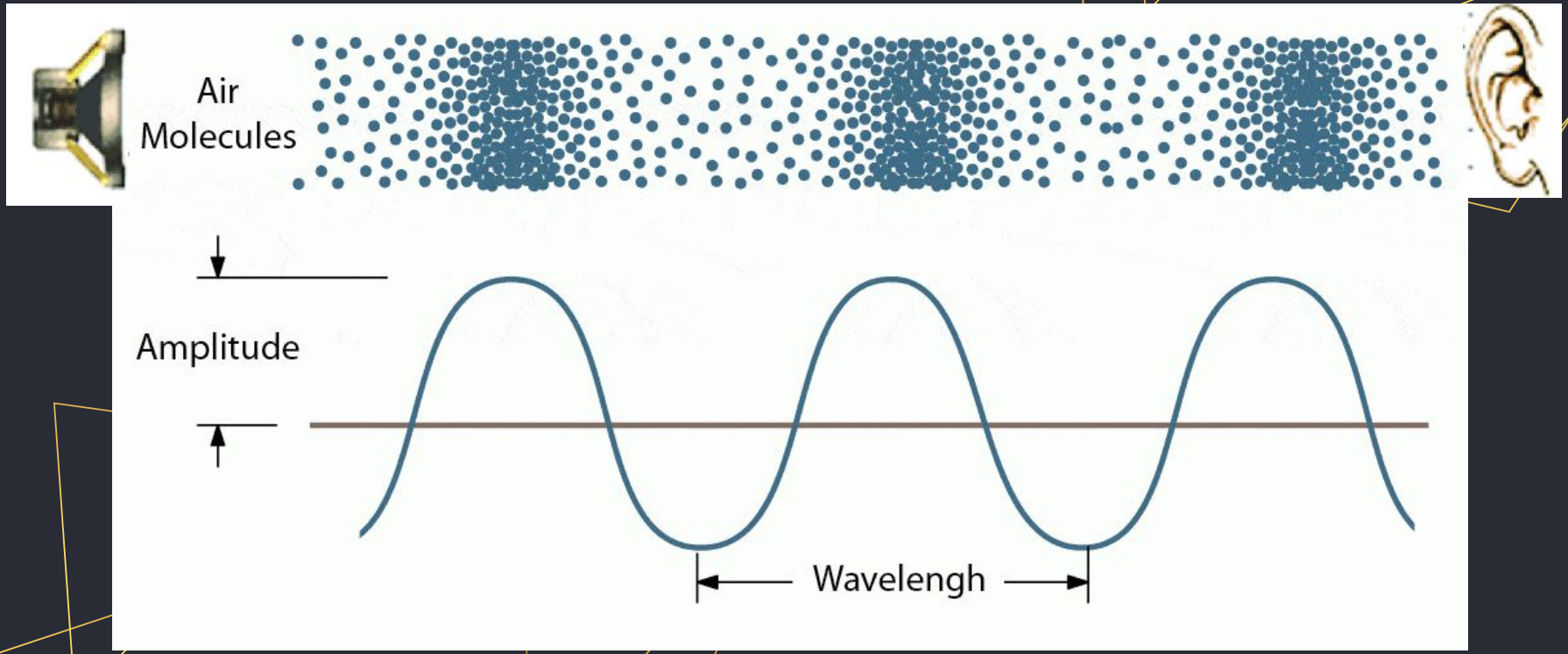


Other problems

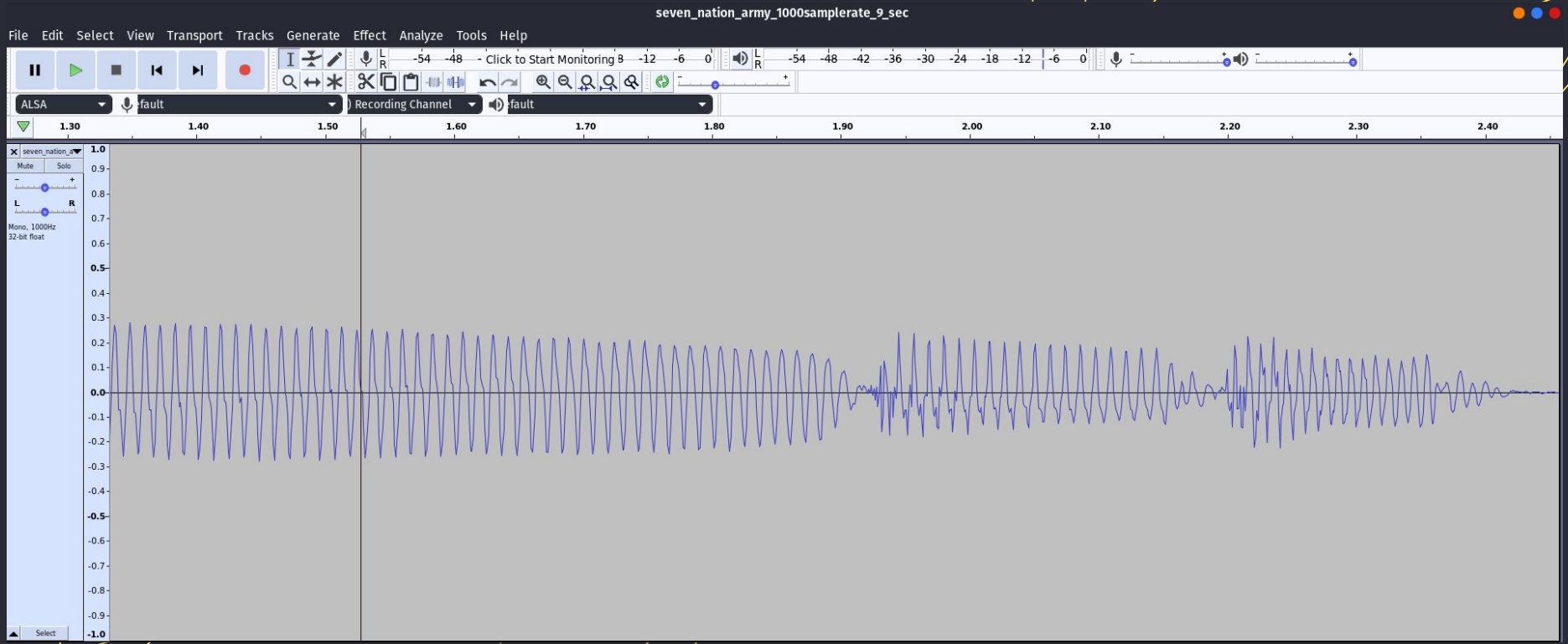
	Their study	Our study
Photodiode	382$ PDA100A2	6$ BPW20RF
ADC	16-bit ADC NI-9223	12-bit stm adc (16 times less precise)
Speaker	60-watt Logitech Z533	16-watt jbl flip 4
Teleskope	~1000$ with 35mm lens	-



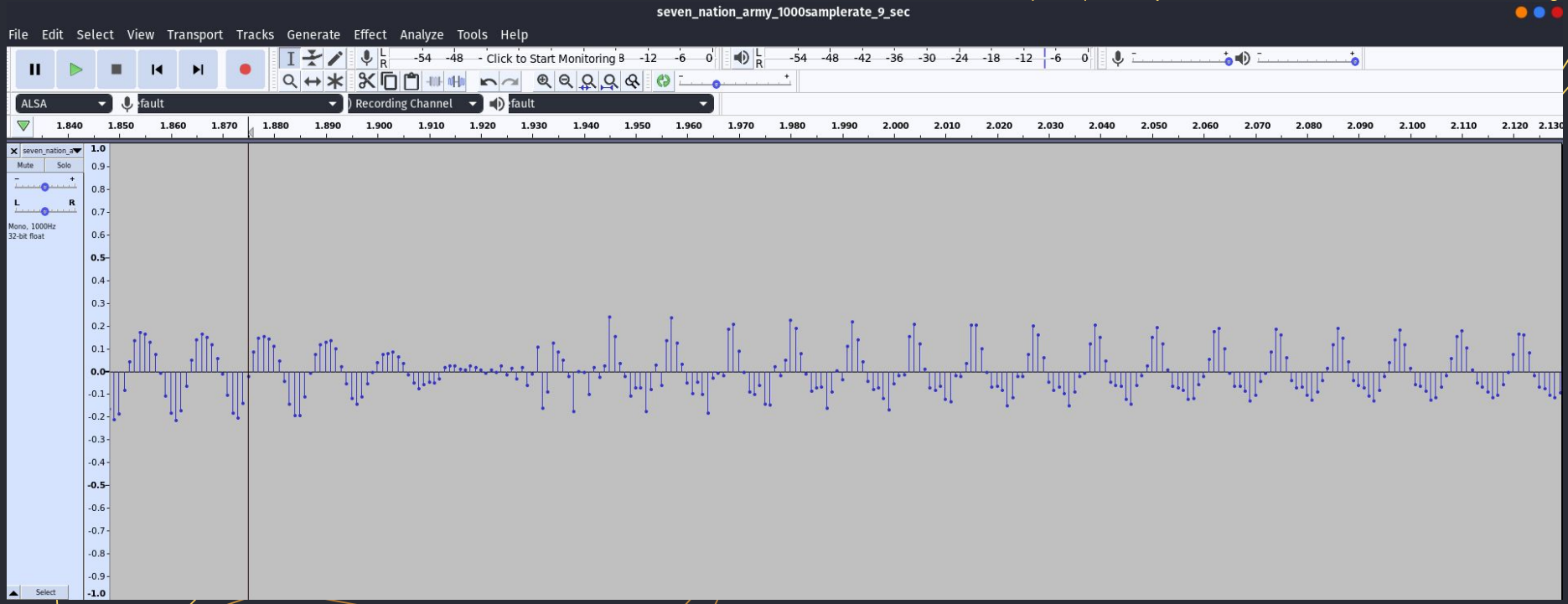
How do we emulate a sound wave?



Wav file

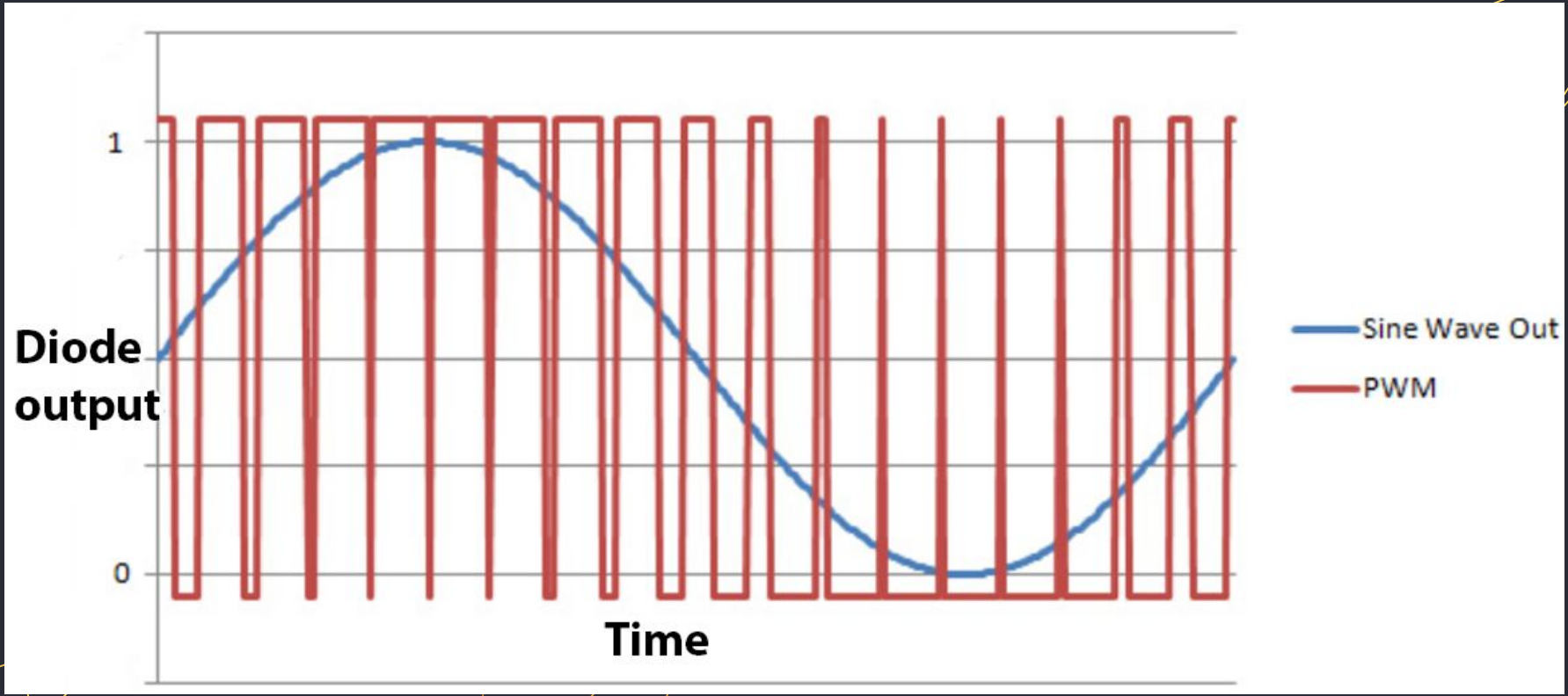

seven_nation_army_1000samplerate_9_sec
File Edit Select View Transport Tracks Generate Effect Analyze Tools Help
Click to Start Monitoring
ALSA
Recording Channel
Mute Solo
Mono, 1000Hz
32-bit float
Select

Wav file

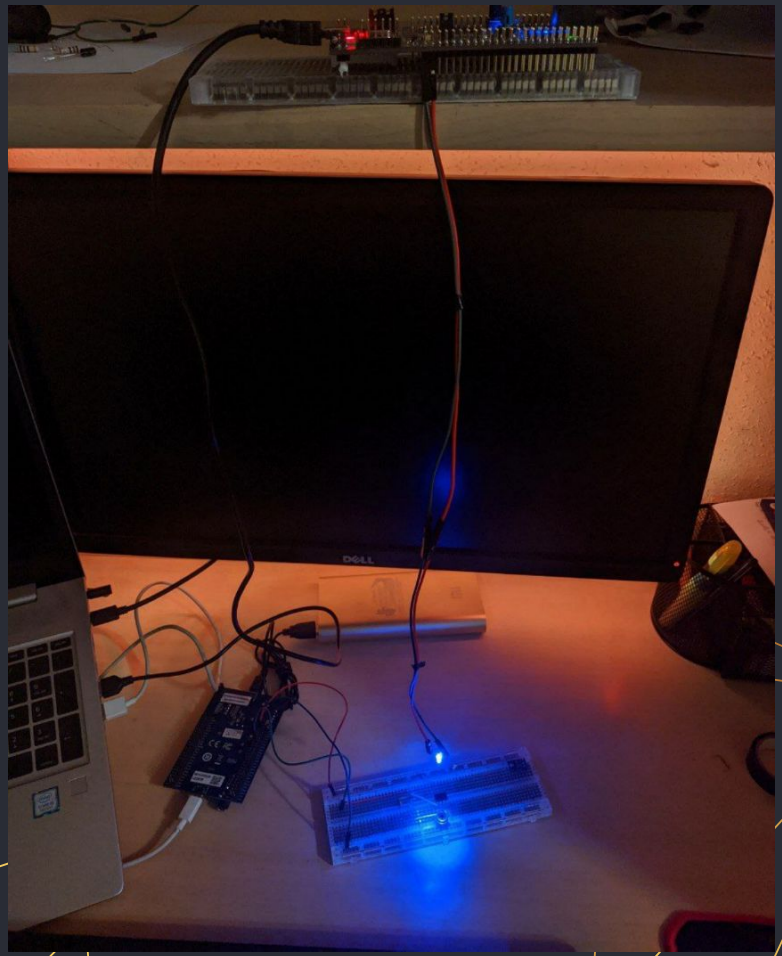


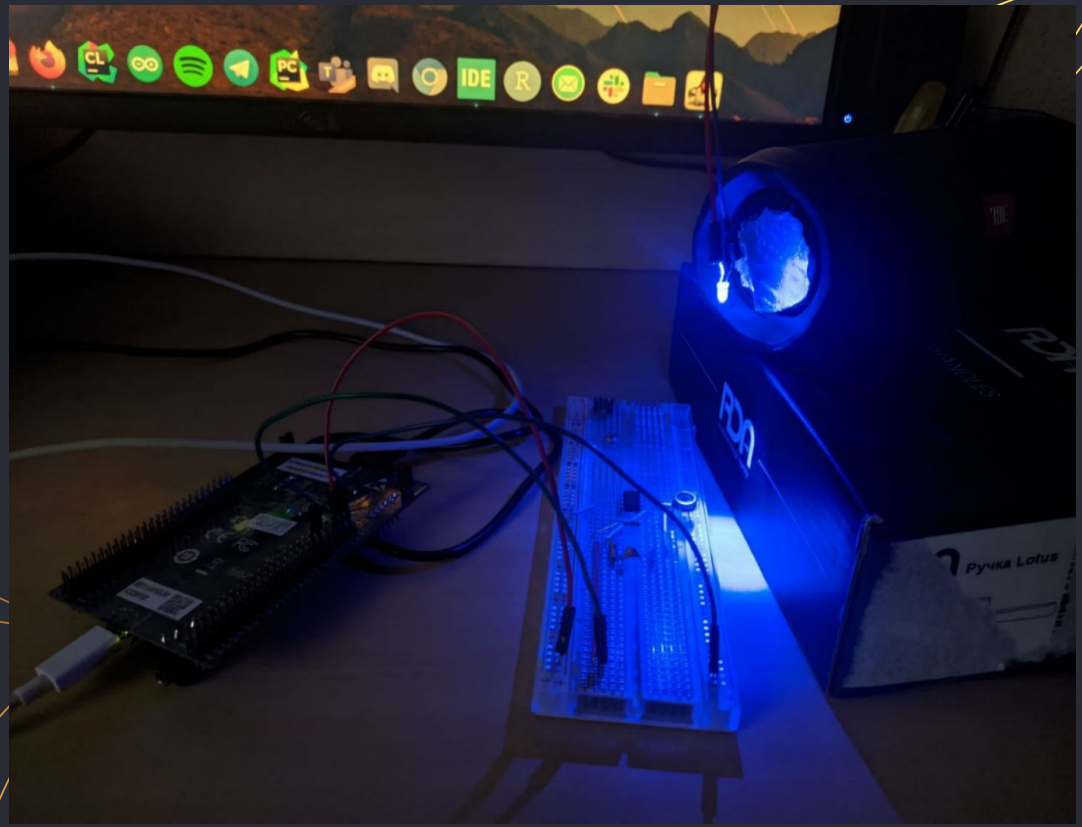

```
"samplerate": 4000,
"data": [16384, 16384, 16384, 16384, 16384, 16384, 16384, 16384, 16384, 16384, 16384, 16384, 16384, 16385, 16384,
```

PWM



PWM

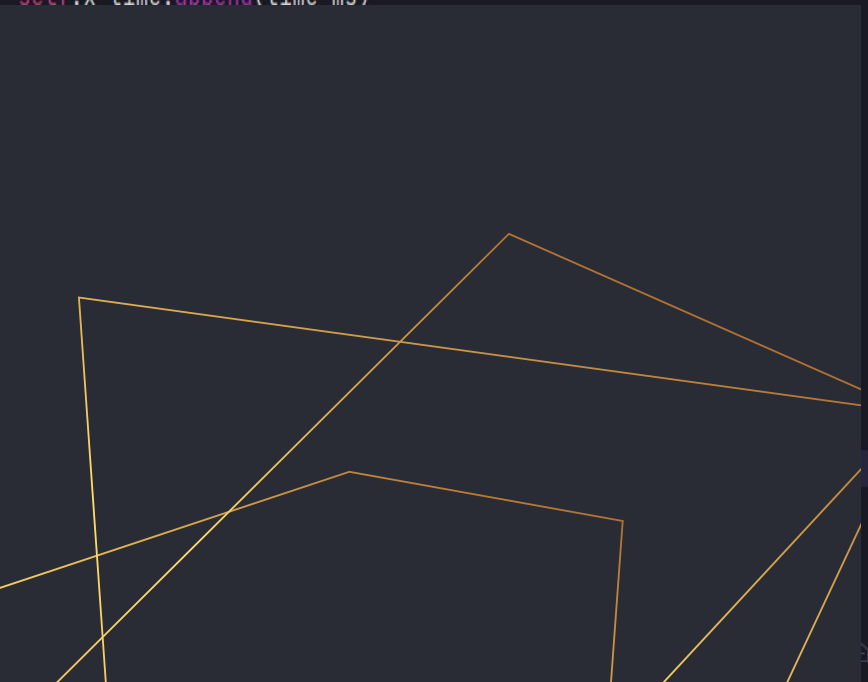




```
# converting both values to int to plot later, and removing \n and \r
value, time_us = tuple(map(int, string_n.rstrip().split()))
time_ms = self.us_to_ms(time_us)
# print(string_n, end="")
if value > 1000:
    print("sth wrong", string_n)
    return

self.y_data.append(value)
self.x_time.append(time_ms)
```

Scaling/normalizing received data



```
time_ms = s.x_time[-1]
wav_wave = s.y_data
samplerate = 1000 * len(s.y_data) / time_ms

wav_wave = np.int16(wav_wave)

# scaling around the mean
mean = int(sum(wav_wave) / len(wav_wave))
print("Mean:", mean, len(wav_wave))
wav_wave = wav_wave - mean

# scaling the wave:
scaler = int((30000 // 2) / max([abs(min(wav_wave)), max(wav_wave)]))
wav_wave *= scaler
print("scaler:", scaler)

# converting to wav
import scipy
from scipy import io
from scipy.io import wavfile
scipy.io.wavfile.write("received.wav", int(samplerate), wav_wave)
```

Results

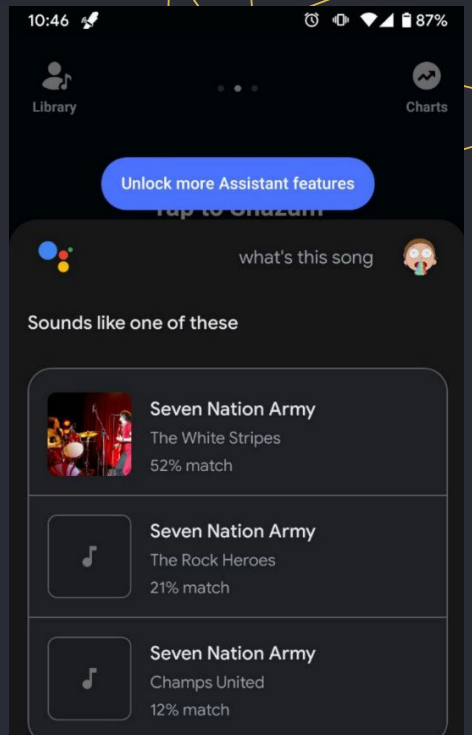
Original track

Retrieved one

Results

Original track

Retrieved one



Results

Original track

Retrieved one

Original track

Retrieved one

Results

Original track

Retrieved one

Results

Original track

Retrieved one

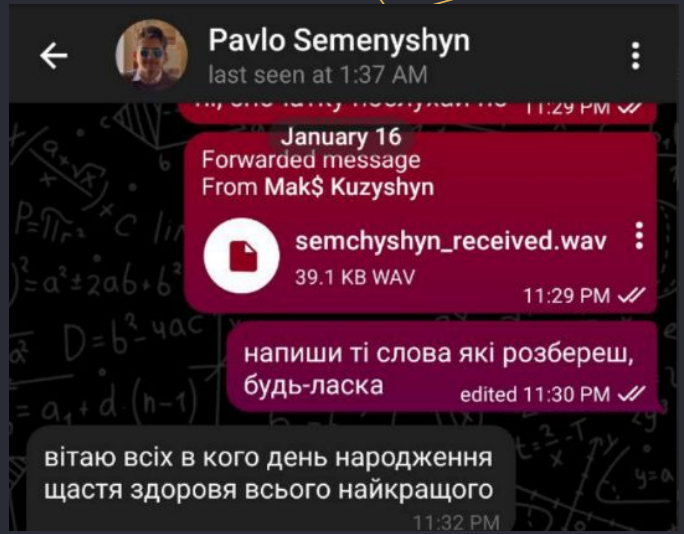
Вітаю всіх, в кого день народження!
Щастя, здоров’я, всього найкращого

Results

Initial track

Retrieved one

Вітаю всіх, в кого день народження!
Щастя, здоров’я, всього найкращого!



Плани на найближче майбутнє

1 етап

Настроїти частоту зчитування світла до діапазону 16-20000 Гц

2 етап

Збільшити чутливість фоторезистора для ідентифікації найменших коливань

3 етап

Сфокусувати світло на фоторезистор за допомогою телескопа/мікроскопа

4 етап

Конвертувати дані з датчику в звук за допомогою сирого алгоритму

5 етап

Розробка оптимального алгоритму, отримання більш-менш розбірливого звуку

What we have learned

1. **What is sound?**
   Basic notion of sound. What a sound wave is, and how is it produced.

2. **Arduino ide**
   We stated of with esp8266 wifi module arduino, and used Arduino IDE.

3. **Stm ADC/Interrupts/DMA**
   Reading analog input using DMA, custom adc interrupts on rising/ falling edge, timers, USB transmitting.

4. **PWM**
   Simulated real sound using pulse-width modulation. Prescaler/period values...

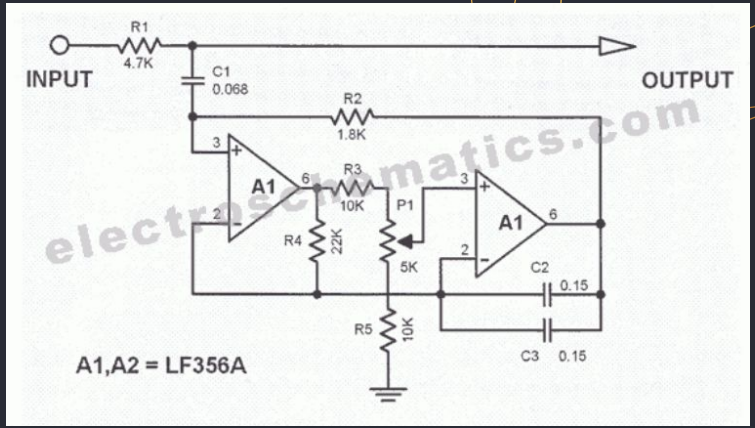
5. **Sound filtration/normalization**
   How sound is stored in memory. Filtrating & scaling received data.

6. **Circuit building**
   The Transimpedance amplifier circuit uses the operational amplifier to amplify photodiode measurements.

Lamphone's future?

- Design a notch filter to filter 50 Hz electric grid signal (*picture on the right*). Then, I assume, we would be able to get signal using light diode vibrations.

50 Hz Ripple filter circuit



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- New **expensive** equipment is required to get any signal from a real lighning bulb.

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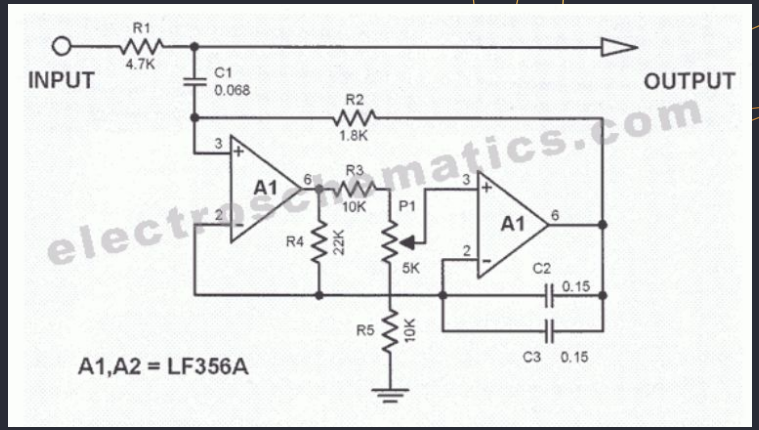
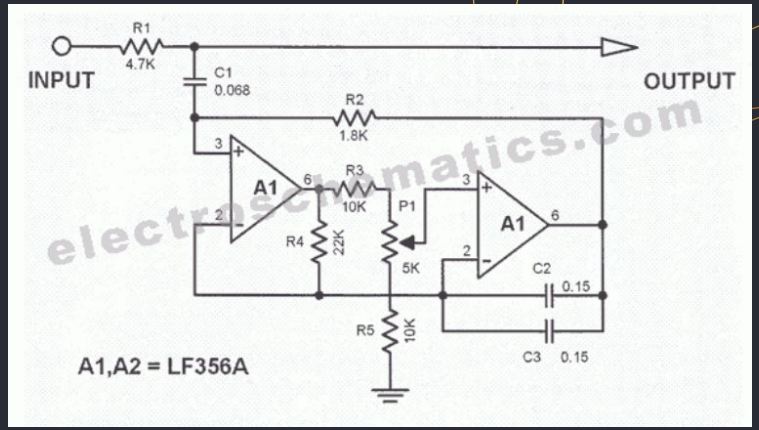
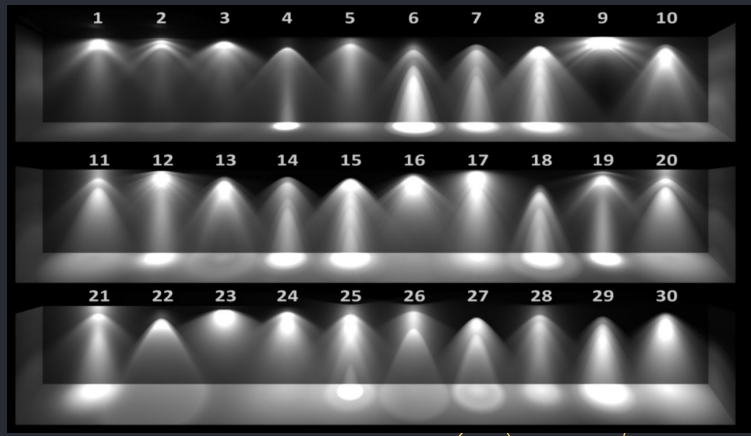


Lamphone's future?

- Design a notch filter to filter 50 Hz electric grid signal (*picture on the right*). Then, I assume, we would be able to get signal using light diode vibrations.
- New **expensive** equipment is required to get any signal from a real lighning bulb.
- Afterwards, we need to find a bulb or diode such that positive/negative shift in angle will proportionally be reflected by positive/negative light intensity on photodiode

50 Hz Ripple filter circuit






Thanks for your attention
And keep in mind, that you are being watched
(not really)

Lamphone

Any questions?

github.com/UKU-mentoring-abench/lamphone-1